AD-A143 395 M577 FUZE PRODUCT IMPROVEMENT PROGRAM: REDESIGNED SETTING AREA(U) HAMILTON TECHNOLOGY INC LANCASTER PA A L MEISSNER ET AL. JAN 83 ARLCD-CR-82064 1/1

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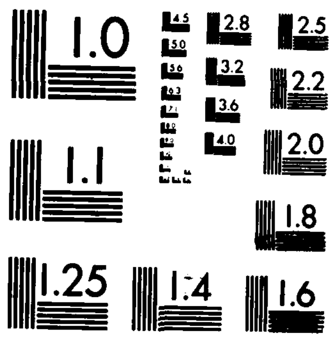

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CONTRACTOR REPORT ARLCD-CR-82064

M577 FUZE PRODUCT IMPROVEMENT PROGRAM: REDESIGNED SETTING AREA

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JANUARY 1983

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LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: Contractor Report ARLCD-CR-82064	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): M577 FUZE PRODUCT IMPROVEMENT PROGRAM: REDESIGNED SETTING AREA	5. TYPE OF REPORT & PERIOD COVERED: Final, Oct. 1980 to Sept. 1982
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): A. Lucille Meissner, Hamilton Technology, Inc.; Thomas W. Perkins, Project Engineer, ARRADCOM; Edwina Chesky, Project Leader, ARRADCOM	8. CONTRACT OR GRANT NUMBER(s): DAAK10-80-C-0203
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Hamilton Technology, Inc., P.O. Box 4787, Lancaster, PA 17604	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Task 2
11. CONTROLLING OFFICE NAME AND ADDRESS: ARRADCOM, TSD, STINFO Div. (DRDAR-TSS), Dover, NJ 07801	12. REPORT DATE: Jan. 1983
	13. NUMBER OF PAGES: 25
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M577 fuze
Setting gear and pinion assembly
Setting shaft
Timer housing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this task was to simplify the setting area of the fuze by eliminating one setting gear and pinion assembly, by changing the material of the setting shaft, by changing the fabrication processes of the parts, and by investigating new designs for the setting shaft and timer housing. The proposed design replaces the current stainless steel setting shaft with an aluminum setting shaft. No other changes to the setting area were made. The projected cost savings is $.25 per fuze.

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TABLE OF CONTENTS

1.0 INTRODUCTION

This report describes the work performed by Hamilton Technology, Inc. for ARRADCOM under Task #2 of Contract DAAK10-80-C-0203 from ~~December~~ OCT. 1980 through ~~August~~ SEPT. 1982. This contract is a product improvement program aimed at reducing the cost and enhancing the producibility of the M577 MTSQ Fuze.

The objective of Task #2 was to simplify the setting area of the fuze by eliminating one Setting Gear and Pinion Assembly, change material, fabrication processes and design of the Setting Shaft and the Timer Housing.

In the current design, there are two identical Setting Gear and Pinion Assemblies engaging 180° apart with a machined stainless steel Setting Shaft. These three subassemblies are held in position by a deep-drawn stainless steel Timer Housing. The elimination of one Setting Gear and Pinion was investigated. Changing the method of manufacturing and material of the Setting Shaft was pursued. Using a die-cast Timer Housing, instead of the current deep-drawn part, was investigated.

2.0 SUMMARY OF ACCOMPLISHMENTS

The objective of this task was to reduce the cost of the fuze by simplifying the setting area of the fuze. Three specific areas of the setting area were considered. They were the Setting Gear and Pinion, Timer Housing and Setting Shaft.

First, tests were performed to determine if one of the two Setting Gear and Pinion Assemblies could be eliminated. After strength and yield tests were performed, it was decided the strength and accuracy of the setting mechanism would be decreased by eliminating one of these assemblies. Changes to the design and material of the Pinion were investigated, but no design could be found that maintained the current strength and accuracy of the setting mechanism.

New designs and materials were considered to develop a lower-cost Timer Housing. Calculations and tests were done on using die-cast Zinc in place of the current stainless steel material. Test results showed that without an extensive design modification to the Counter Assembly a die-cast Timer Housing does not have adequate strength. It was decided the non-recurring cost and the risk involved was too high to justify continuing this development.

The material of the Setting Shaft was changed from 416 stainless steel to 7075 aluminum. The outside diameter above the knurl was changed from .222 - .001 inch to .2175 - .001 inch in order to accommodate the current Clutch Grip Ring. The acceptable slip torque was changed from 9 to 13 in.-lbs. to 10 to 14 in.-lbs.

The final result of this task was to change the material of the Setting Shaft to 7075 aluminum. This new design passed all qualification tests. It results in a projected cost savings of $.25 per fuze without G&A, profit or tooling cost.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The 7075 aluminum Setting Shaft was subjected to laboratory and ballistic acceptance tests with successful results. The 7075 Aluminum Setting Shaft, with a projected cost savings of $.25 per fuze, is recommended for incorporation in the M577 MTSQ Fuze Technical Data Package. No other changes to the setting mechanism are recommended.

4.0 TECHNICAL DISCUSSION

4.1 Introduction

Three areas of the setting timer mechanism were investigated in an effort to lower costs. The specific areas considered were eliminating one Gear and Pinion, changing materials and design of the Timer Housing, and changing materials and manufacturing methods of the Setting Shaft. Each of the next three sections discusses the technical approach used to investigate each of these three areas.

4.2 Setting Gear and Pinion Assembly

An investigation was conducted to determine whether one of the two Setting Gear and Pinion Assemblies could be eliminated. Various tests were conducted to compare strength and yield of the setting mechanism using one and two Setting Gear and Pinion Assemblies. Ultimate strength tests of the setting mechanism showed the ultimate strength is 38 to 40 in.-lbs. with two Setting Gear and Pinion Assemblies and only 17 to 26 in.-lbs. with one Setting Gear and Pinion Assembly. Yield tests of the setting mechanism at 15 in.-lbs. of torque showed eliminating one assembly tripled the yield of the setting mechanism from 1.8° to 6.5°. The durability of the setting mechanism with one Setting Gear and Pinion Assembly was tested by setting the unit to 200 seconds and back to zero repeatedly. Five out of six units did not survive ten trials. Based on the test results, it was decided one Setting Gear and Pinion Assembly with the present configuration does not provide an accurate setting mechanism.

Changes to the pinion design were considered to increase the yield and ultimate strength. The effect in strength of changing the pinion tooth from 20° to 25° pressure angle was calculated. This calculation showed an increase in strength of 47% and an increase in contact ratio from 1.0 to 1.3. Pinion and corresponding Setting Ring Gear tooling were obtained to further investigate this option. The Setting Ring Gear was made of beryllium copper rather than 301 Stainless Steel. Testing of the setting mechanism with 25° pressure angle pinions and ring gears did not agree with the calculations. Some pinions and ring gears failed as low as 20 in.-lbs. when only one Setting Gear and Pinion Assembly was used.

Alternate high strength materials for the Setting Pinion were considered. Data on yield and ultimate strength for steel alloy 4140 and stainless steel 17-4ph material were extrapolated from tests with 416 stainless steel using the ratio of the ultimate tensile strength of the materials. No configuration with one Setting Gear and Pinion Assembly had a yield comparable to the current production unit. The possibility of eliminating one Setting Gear and Pinion Assembly was abandoned.

4.3 Timer Housing Assembly

Various designs of the Timer Housing using die-cast Zinc were studied and tested to develop a lower-cost Timer Housing. The Timer Housing was redesigned by increasing the thickness of the top section and increasing the radius to .050" where the top and side wall meet.

The redesigned Timer Housings were first machined from aluminum to simulate the strength of a die-cast part. Static tests on these parts showed the aluminum parts had adequate strength to withstand the load from 30,000-g setback. These tests also revealed adequate rigidity when compared to the current Timer Housing.

A sample lot of die-cast Timer Housings, made from Zinc Alloy 3 and 12, were ordered from Cambridge Tool. Static test results showed the die-cast Zinc Timer Housing does not have adequate strength to support 30,000-g setback load. The Timer Housings, made from both Zinc Alloy 3 and 12, failed at static loads equivalent to 11,000-g and 15,000-g setback, respectively.

Various solutions to the low strength problem were considered. The die-cast Timer Housings were annealed and then statically tested. Test results showed no improvement in strength. Static tests were done using machined Zinc (ZA12) Timer Housings to determine the relationship between the thickness of the top section and the compressive strength of the part. The strength increased as the thickness increased, but the relationship is not linear. The increase in strength by increasing the thickness was not sufficient to obtain the required strength.

Since no way was found to increase the strength of the Timer Housing sufficiently, the possibility of reducing the high bending stress was considered. The high bending stress applied to the top of the Timer Housing is due to the concentrated load through the Counter Body. The bending stress can be reduced significantly by shortening the length of the Counter Body so the load will be applied to the Timer Housing through the Counter Wheels. Since the Counter Wheels are further outboard, the bending stress would be reduced. It is necessary to redesign the Counter Wheels in order to do this because the current Wheels are not rigid or large enough to prevent the Counter Body from hitting the top of the Timer Housing. Test results showed shortening the Counter Body and increasing the outside diameter or changing the material of the Counter Wheels increased the static load capacity of the die-cast Timer Housing to the equivalent of 30,000-g setback. However, these design modifications are not desirable because of the development cost and risk. The development of a die-cast Timer Housir was discontinued.

4.4 Setting Shaft

Several materials and manufacturing processes were studied in order to decrease the cost of the Setting Shaft. Since the Setting Shaft is now made of bar stock, most of the original material is removed. Most of the machining of the Setting Shaft could be eliminated by making the shaft as an assembly of commercial tubing and a machined pinion. The outside diameter of the tubing would have to be turned down because of the tolerance required. The cost of stainless steel tubing plus the necessary machining proved to be too high to offer an overall cost savings for the Setting Shaft. This concept was abandoned.

Strength tests showed the Setting Shaft is not the weakest component of the setting mechanism. These strength tests indicated the Setting Pinion or Setting Ring Gear is the first component to fail. Therefore, materials with less strength than the stainless steel now used were investigated for the Setting Shaft. Aluminum 7075, T6, one of the highest strength aluminum alloys available, was chosen. Strength tests showed the aluminum Setting Shaft is not the weakest component of the setting mechanism. These tests indicated the Setting Pinion or Setting Ring Gear is still the first component to fail.

Since static tests showed the strength of the aluminum Setting Shaft is adequate, tests were performed with the current Grip Rings on the aluminum Setting Shaft. The torque required to slip the Grip Rings was measured with various outside diameters of the Setting Shaft. A diameter of .2175 - .0010 in., which is .0045 in. smaller than the diameter of the current stainless steel Shaft, was chosen.

An aluminum Setting Shaft with hard-coat anodizing was also tested. The static yield tests with this Setting Shaft had excellent results; however, the tests with the Grip Rings showed the hard-coat surface was not satisfactory. An aluminum Setting Shaft with the hard coat on the pinion teeth only was tested successfully, but this design does not offer any cost savings. This design does not offer any cost savings because the cost of hard coating only the pinion teeth was far more expensive than hard coating the entire Setting Shaft.

Setting Shafts for testing were manufactured with the same methods used for the current stainless steel Shaft. Acceptance tests, consisting of durability, setting accuracy, slip torque and ballistic tests, were completed successfully (see Section 5). Control units were also tested for comparison purposes.

5.0 TESTING

5.1 Slip Torque Tests

Slip torque tests were done with three different Setting Shafts: aluminum, stainless steel and hard-coated aluminum. The torque required to turn the Grip Rings relative to the Setting Shaft was measured. The test was repeated using from 5 to 12 Grip Rings. Each Setting Shaft was checked for galling after the test. No galling was present on the bare aluminum or stainless steel Shaft; however, the hard-coated aluminum shafts had loose flakes of hard coat and some galling. The slope of the torque versus Grip Rings of the aluminum Shaft is approximately the same as that of the stainless steel Shaft. Since the acceptable slip torque is proposed to be 10 to 14 in.-lbs. rather than the current 9 to 13 in.-lbs., the diameter of the aluminum Shaft was chosen to provide a higher slip torque than the current stainless steel Shaft. The results of this test are shown in Figure 1.

5.2 Durability and Zero Set Tests

Tests, consisting of setting each fuze to 200 seconds and back to zero ten times, were performed on fifteen fuzes with aluminum Setting Shafts and fifteen control fuzes. In both groups, the Grip Ring slip torque was measured periodically. One unit with an aluminum Setting Shaft became unsettable in the ninth trial because the Grip Ring slip torque fell below the setting torque. Upon examination, it was observed that one Grip Ring had an unusually sharp edge on it which cut a groove in the Shaft. The slip torque of most of the test units decreased during the ten trials. Therefore, the acceptable range of slip torque was increased from 9 to 13 in.-lbs. to 10 to 14 in.-lbs. to provide a larger gap between the maximum setting torque and minimum slip torque. Unit-by-unit results for this test are shown in Table 1.

The same test, described in the previous paragraph, was repeated on five test and five control fuzes; only this time, any change in the zero set of the fuze was measured after each trial. One of the control units could not be set in the tenth trial because the slip torque had deteriorated until it was less than the setting torque.

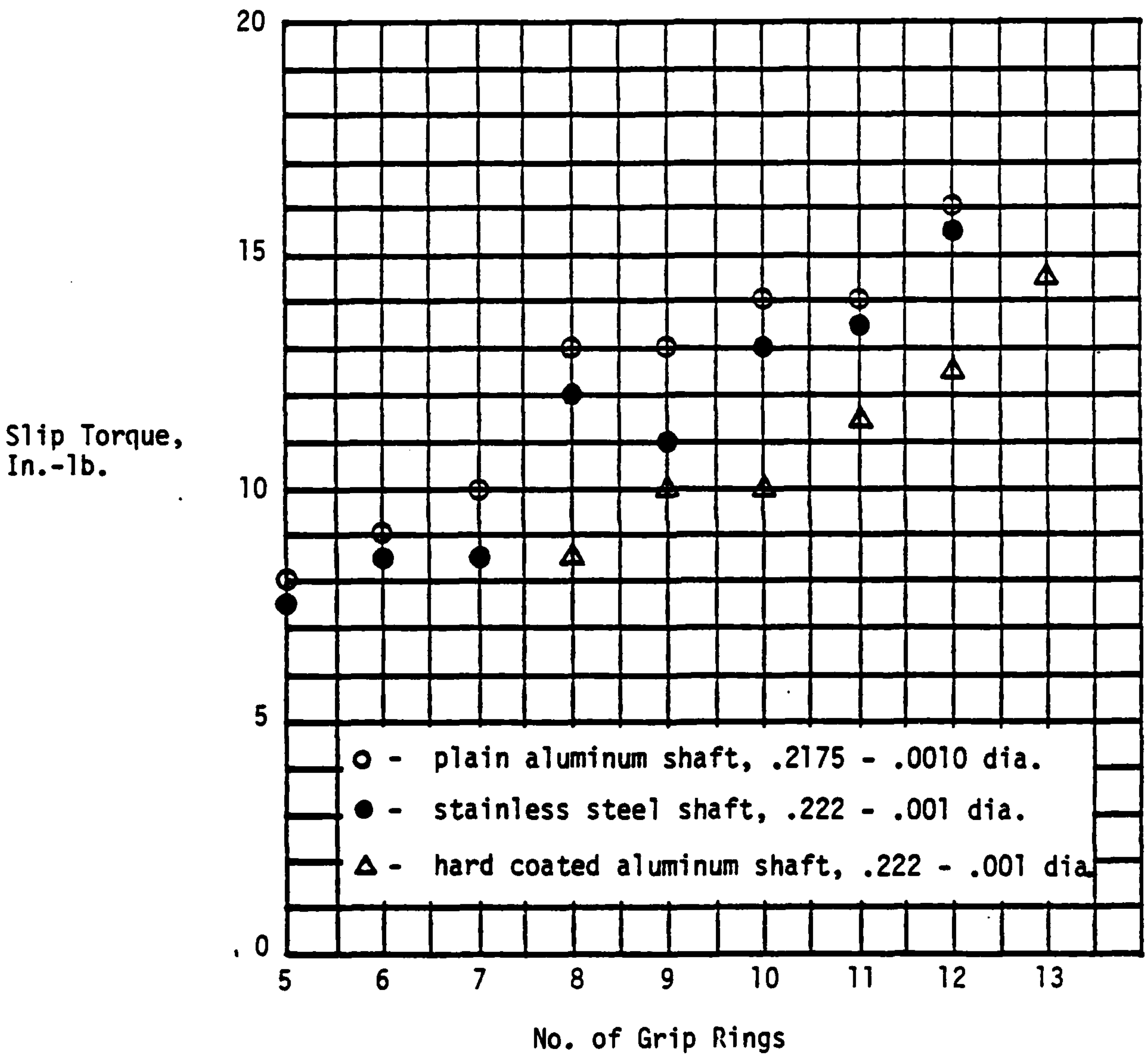


Figure 1 Grip Ring Torque Tests

TABLE 1
CRANKING TEST RESULTS

Units with Aluminum Setting Shafts

Unit No.	Pre-Test Torque (in.-lb.) Setting	Slip	Post-Test Torque (in.-lb.) Setting	Slip
1	5.5	9.5	5	8
2	5.5	10.5	4.5	10
3	6.5	11	5.5	10.5
4	8	11.5	5.5	10.5
5	6	12.5	5.5	9
6	6.5	12	5.5	9.5
7	8	11	6	10
8	6	12	6	10.5
9	7	11	6	9.5
10	8	10.5	7	7.5 (failed during ninth trial)
11	6	12.5	5	10.5
12	6	10.5	5.5	10
13	7	11	7	9.5
14	5.5	11	5.5	9.5
15	7.5	12.5	5.5	9

Units with Stainless Steel Setting Shafts

Unit No.	Pre-Test Torque (in.-lb.) Setting	Slip	Post-Test Torque (in.-lb.) Setting	Slip
1	7	10.5	6	11
2	7	12.5	5	13
3	7	11	7	11.5
4	8	12	5.5	12
5	7	13	6.5	13
6	7	13	5.5	13
7	7	13	5	12
8	6	13	4.5	13
9	6.5	13	6	12.5
10	7	11.5	6	12.5
11	7	12	6.5	12.5
12	7.5	12	6.5	12.5
13	7	12.5	5	13.5
14	7	11.5	5.5	12
15	7	11	7	11.5

The change in the zero set observed was not significantly different in the test units than in the control units. Test results are shown in Table 2.

5.3 Ballistic Tests

Thirty (30) fuzes, containing an aluminum Setting Shaft, and thirty (30) control fuzes were built and shipped to Yuma Proving Grounds for ballistic testing. The test units were built using 10 to 14 in.-lbs. for the slip torque specification. The units were successfully tested in the 155mm, 198 System, Zone 8, ambient at 90- and 3-second time setting. The round-by-round results are shown in Table 3.

TABLE 2
ZERO SET CHECK TEST RESULTS

Units with Aluminum Setting Shafts

Unit No.	Pre-Test Torque (in.-lb.) Setting	Slip	Post-Test Torque (in.-lb.) Setting	Slip	Change in Zero Set (sec.)
1	7	9	5	8	0
2	6.5	10.5	7	8	.05
3	7.5	11	4	8.5	.1
4	5	11.5	4.5	8	0
5	7	9.5	4.5	9	.05

Units with Stainless Steel Setting Shafts

Unit No.	Pre-Test Torque (in.-lb.) Setting	Slip	Post-Test Torque (in.-lb.) Setting	Slip	Change in Zero Set (sec.)
1	8	12	Failed in 10th trial		.1 (after 9 trials)
2	5	12.5	5	14	.05
3	5	12	4	11.5	0
4	6.5	13	5	8	0
5	8	12	5	10.5	0

TABLE #3
BALLISTIC TEST RESULTS

Gun: 155mm, 198 System, Zone 8

TEST UNITS

Time Setting 90 Sec. Fuze	Time	Time Setting 3 Sec. Fuze	Time
1	89.944	16	3.002
2	90.154	17	2.967
3	89.830	18	3.046
4	89.987	19	3.015
5	90.024	20	3.003
6	90.083	21	3.057
7	89.919	22	2.961
8	90.159	23	3.005
9	89.930	24	2.990
10	90.073	25	3.059
11	89.929	26	3.037
12	89.909	27	2.989
13	90.374	28	3.000
14	89.962	29	3.021
15	90.021	30	3.046
	$\bar{X}$ = 90.020		$\bar{X}$ = 3.013
	S.D. = .135		S.D. = .031

CONTROL UNITS

Fuze	Time	Fuze	Time
1	90.189	16	3.037
2	89.846	17	2.978
3	90.084	18	3.058
4	90.085	19	3.042
5	89.824	20	2.980
6	90.157	21	2.995
7	89.862	22	3.042
8	89.921	23	2.992
9	89.993	24	2.970
10	90.097	25	2.985
11	89.925	26	3.089
12	89.894	27	3.003
13	89.520	28	2.965
14	90.129	29	3.140
15	90.048	30	3.072
	$\bar{X}$ = 89.972		$\bar{X}$ = 3.023
	S.D. = .173		S.D. = .051

6.0 COST AND WEIGHT

6.1 Cost Comparison

A cost comparison of the current Setting Shaft and proposed Setting Shaft is shown in Table 4. The cost of the proposed design is based on a quantity of 300,000 units. The projected cost savings is $.25 per fuze. This cost savings results from a lower material cost and a decrease in machining time for aluminum. These costs do not include tooling, G&A or profit. The projected cost of tooling is $1,373.

6.2 Weight

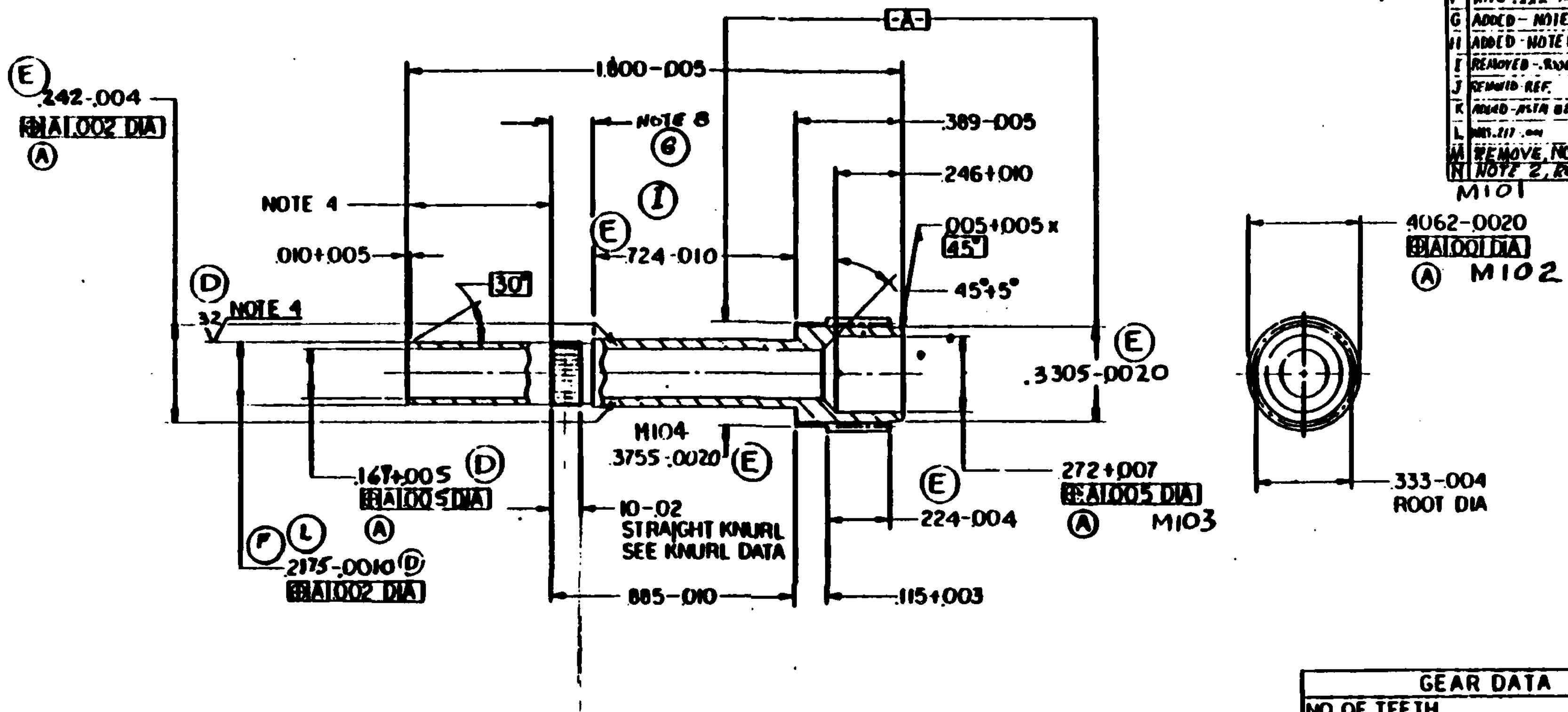
Replacing the stainless steel Setting Shaft with an aluminum Setting Shaft decreases the weight of the fuze by .0081 pounds. This is an insignificant change in weight.

TABLE 4

COST COMPARISON

	Present Design ($)	Proposed Design ($)	Savings
Make	.7536	.5077	.2459
Inspect	.0875	.0875	0
Total	.8411	.5952	.2459

APPENDIX



STRAIGHT KNURL DATA PER ASA B 94.6-1966	
NO. OF TEETH	28
DIAMETRAL PITCH	128
BLANK DIA	.222-.003
KNURLED DIA	.231

(J)

GEAR DATA	
NO. OF TEETH	24
DIAMETRAL PITCH	64
PRESSURE ANGLE	20°
PITCH DIAMETER	.3750
TOOTH FORM	INVOLUTE
CIRCULAR THICKNESS	.02454
AGMA QUALITY NO.	8A
TOTAL COMPOSITE ERROR	.002 (NOTE 7)
TOOTH TO TOOTH COMPOSITE ERROR	.001 (NOTE 7)
WHOLE TOOTH DEPTH	.0364

NOTES –
1- SPEC MIL-A-2550 APPLIES.
(N) (K) 2- MATERIAL:- ALUMINUN ALLOY BARS, RODS AND WIRE, ALUMINUM ALLOY 7075 T6, ASTM B211.
(M)

4- 32/ APPLIES TO LENGTH SHOWN.
5- 125/ ALL OVER, EXECPT AS NOTED.
6- UNLESS OTHERWISE SPECIFIED FILLETS ARE TO BE .005R MAX AND CORNERS ARE TO BE .005R MAX OR .005 MAX x 45° BASIC.
(D) 7- .003 TOTAL COMPOSITE ERROR AND .002 TOOTH TO TOOTH COMPOSITE ERROR PERMITTED PROVIDED THE REQUIREMENTS OF DWGS. 8236569, 9236500 AND 9236700 ARE MET.
(H) 8- .222 -.003 BLANK DIAMETER FOR KNURL APPLIES TO LENGTH SHOWN.

A/M 19
A/M 21
A/M 24

	EAR7200346-1		
A	NOR7500069-1		
B	NOR7500406-1		
C	NOR7500942-1		
D	[illegible]		
E	NOR7600286-1		
F	WAS .222-.004		
G	ADDED - NOTE 8		
H	ADDED - NOTE A		
I	REMOVED - [illegible]		
J	REMOVED REF.		
K	ADDED - ASTM B211		
L	WAS .222 -.004		
M	REMOVE NOTE 3		
N	NOTE 2, REVISED		

58089

PART NO. 9236592

SHAFT, SETTING

28 AUG 1972

D 19203 SK5911

58087

9236580

APPLICATION

PART NO. 9236569 - THREE MODULE ASSEMBLY

Sheet 1 of 2

Change Note 7 from: ASSEMBLE RING, GRIP, CLUTCH (AS REQUIRED) SO THAT THEY SHALL SLIP AT A RADIAL TORQUE of 9.0 + 4.0 INCH POUNDS.

to: ASSEMBLE RING, GRIP, CLUTCH (AS REQUIRED) SO THAT THEY SHALL SLIP AT A RADIAL TORQUE OF 10.0 + 4.0 INCH POUNDS.

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